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NUCLEAR ENERGY AND RENEWABLE ENERGY IN URBAN ENVIRONMENT

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Abstract. Increasing demand for electricity is inevitable due to swiftly growing population of the world and the endless desire of people to strive for better and more comfortable lives. Producing more energy while reducing greenhouse gasses is a difficult task for many countries. It is because of challenges finding the best long-term solution to meet people's expectations and to reduce the development of global warming and the adverse effects. In order to achieve the goals of European Union regarding the share of renewable energy sources in final energy consumption, countries are forced to increase their green energy potential by integrating renewable energy sources into urban environment. The aim of the research is to study the future perspectives of the energy sector and possible consequences, focusing on the territory of Latvia. Authors use umbrella review, literature review and state-of-the-art review to explore the renewable energy potential of Latvia. It mainly relies on the development of biomass and biogas. Research considers possible integration of nuclear energy into Latvia, but results of the survey reflect negative public opinion on nuclear energy, giving priority to renewable energy sources. Authors, using the specialized program 'ARGOS', made predictions about the consequences of a nuclear accident, assuming that there is a leak of radioactive substances from one of the nuclear power plants close to Latvia, located either in Sweden, Finland or Russia. In these cases main preventive measures such as taking Iodine pills, staying indoors and following the information from media are considered.

Key words: *renewable energy, nuclear energy, nuclear safety.*

JEL code: R11

Introduction

In the last few years, many countries have been confronted with the challenge of producing more energy to meet their growing energy demand, while at the same time struggling with the issue of reducing greenhouse gas emissions. It is generally believed, that, unless dramatic actions are taken to reduce global warming, the world could face an environmental catastrophe. The International Energy Agency suggests that current trends in energy supply and use are patently unsustainable — economically, environmentally and socially. Without decisive action, energy-related emissions of CO_2 will more than double by 2050 (Apergis, N. et al., 2010). Cities are responsible for more than three-quarters of the emissions of greenhouse gases. It is anticipated that the urban population will increase by up to 80% by the mid-21st century, which will make the current energy model unsustainable, as it is based on the intensive use of fossil resources. Based on that, a change in urban planning is required to meet the energy requirements of cities (Barragán-Escandón, A., Terrados-Cepeda, J., & Zalamea-León, E., 2017). Energy consumption modeling at the urban scale is crucial for supporting a transition towards the low-carbon city (Moghadam, S. T. et al., 2018). From the economic point of view, the change must take place as well, because many countries are concerned about increasing fossil fuels prices, which is a direct result of a growth in worldwide demand of energy (Perea-Moreno, A. J. et al., 2017). Developing renewable energy sources are considered a popular solution to combat fossil fuel price increase meanwhile creating a sustainable national energy policy. There are many good reasons to promote sustainable development and reduce greenhouse gas emissions and other emissions of combustion. The air quality in many urban environments is causing many premature deaths

because of asthma, cardiovascular disease, chronic obstructive pulmonary disease, lung cancer and dementia, what can be associated with emissions of combustions. Estimated global social cost of air pollution is at least $3 trillion/year. To reduce greenhouse gas emissions, the transition to electric vehicles together with electricity generation using renewable energy must take place in line with the goals of the Paris Agreement on Climate Change (Erickson, L. E., 2017). Other research on minimizing air pollution in both directions: reducing emissions through advances in technology and more efficient urban planning. An efficient built environment through appropriate urban planning, supported by energy-efficient vehicles, buildings, appliances and integrated power generation by alternative and renewable sources, can reduce greenhouse gas emissions substantially (Lambrechts, W. & Sinha, S., 2017).

The authors of the article describe possible directions of sustainable energy policy in Latvia, taking into account the potential of renewable energy sources. The aspects of the possible use of nuclear power are being evaluated. Following research methods are used: umbrella review, literature review, state-of-the-art review.

1. Renewable energy sources in an urban environment

Authors provide insight of literature review regarding renewable energy sources and technologies.

Nowadays, debates addressing climate change, fossil fuels depletion and energy security highlight increasing needs for a more sustainable built environment in order to reduce energy consumption and reduce energy emission are trends in the buildings sector. Meeting these targets is a challenge that calls for innovative research to improve the use of renewable energy sources, new technologies, and holistic tools and methodologies. Such research should analyze the dynamics and main drivers of energy supply and demand in buildings to support new policies, plans and indicate actions towards lowering the built environment burdens (Soares, N. et al., 2017).

Fossil fuels are nonrenewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. On the other hand, biomass can be used to produce electricity, transportation fuels, or chemicals. The use of biomass for any of these purposes is called bioenergy. (Zohuri, B., 2018). Striving for a 100% renewable energy system in Europe by the year 2050 would be technically possible by decommissioning nuclear power, achieve significant energy for heating saving, converting the private car fleet to electricity, providing heat in rural areas with geothermal heat pumps, providing heat in urban areas with district heating, converting heavy-duty vehicles to use a renewable electrofuel, and replacing natural gas with methane (Connolly, D., Lund, H., & Mathiesen, B. V., 2016).

Countries worldwide have set national targets for energy production from renewable sources. Yet, while many governments are declaring to be committed to renewable energy production support, actual process to obtain needed permissions off-site installations is becoming increasingly difficult. With increasingly large areas of land used to produce renewable energy, available suitable land plots are becoming increasingly contested. Countries are seeking to meet their renewable targets are directing more attention towards tapping the potential in the urban environment through smaller-scale facilities like small-scale wind turbines (Teschner, N. A. & Alterman, R., 2017).

The development of the Autonomous Power Supply (APS) system based on the so-called energy mix. Such a system works in an isolated arrangement and serves to reliably supply electricity from renewable sources for small residential or public utility devices in an urban area (Fedak, W. et al., 2017). Every European country, which is struggling with the gradual integration of renewable sources in an energy audit, could use this energy mix, which would be a good development milestone towards sustainable energy policy. Many scientists in 2018 have performed several studies about the Baltic Sea region energy policy and European Union studies (Gritsenko, D., 2018; Cucchiella, F., D'Adamo, I., & Gastaldi, M., 2018; Sneum, D. M. et al., 2018; Gnatyuk, V. I. et al., 2018; Силиневич, В. Л. & Калинина, К. Е., 2018).

Renewable technologies in the urban environment have been widely regarded as an increasingly important solution to deal with the climate change challenges and energy security. Significant effort is performed in the integration of photovoltaic panels (PV) and microturbines in the urban context showing a substantial reduction in CO_2 emissions. At the same time, high attention is drawn to an often-overlooked aspect regarding renewable energy technologies, in that despite having low operating costs their overall benefits are often not well understood and consequently are often evaluated as being less profitable than fossil fuel alternatives, even though they are future proof about energy cost (Kolokotsa, D., 2017).

In Germany, rising number of municipalities are striving for energy self-sufficiency. Results of the research show, that environmental awareness, tax revenues and greater independence from private utilities are positively related to the mayor's attitude towards the realization of energy self-sufficiency (Engelken, M. et al., 2016). Energy self-sufficiency can be improved by integrating renewable energy sources into the urban environment, which has a positive impact on solving climate change problems.

Giving the fact, that renewable energy sources have a huge impact on successful sustainable energy policy regarding climate change, the authors of the article in Table 1 offer the summary of the advantages, disadvantages and development perspectives of renewable energy sources in Latvia. Even though wind and solar energy do not require any raw materials, the potential of these energy types in the territory of Latvia is limited. The average wind speed throughout the territory of Latvia is insufficient to provide efficient energy production. Kurzeme coast near the Baltic Sea has a small potential for the development of wind power. Small wind turbines could be integrated into the cities of Kurzeme region. However, it requires research and the measurements of the wind flow in that area. European solar maps show that Latvia on average could produce about 1000 kWh/m^2 per year, which is a small amount compared to other European countries located more south and which shoves minimal solar energy development potential in Latvia (Solargis, 2016). In addition, there are limited options for storing the produced energy as well as wind energy. However, solar panels have a good potential to be deployed on the roofs of the buildings, increasing the self-sufficiency of urban environment. Another renewable energy source, which might be suitable for households, is geothermal energy, which is produced using geothermal heat pumps. The development of geothermal energy in Latvia is baffled by insufficient groundwater temperature in the territory of Latvia. However, there are minimal development opportunities in the southwest and central regions of Latvia (Latvian Environment, Geology and Meteorology Centre, 2018). Water energy takes up a significant part of the produced renewable energy of Latvia (72.7% in 2016). Hydro-electric station generated power is the main reason, why Latvia is among European Union`s leaders regarding the share of energy from the renewable energy sources – 37.6% of consumed energy in 2015 were produced by renewable energy sources, which is the third best indicator in European Union (Central Statistical Bureau of Latvia, 2016; Eurostat, 2017). Largest built hydro-electrical station cascades are on river Daugava, powering hydroelectric power plants 'Keguma HES', 'Plavinu HES', 'Rigas HES', which are efficient energy accumulators. Hydropower already constitutes the greatest share of renewable energy source power in Latvia. However, further hydropower development is available through small hydroelectric power plants. Based on the mineral deposits in the territory of Latvia and forest, which covers 51% of the territory of Latvia (Ministry of Agriculture of Latvia, 2018), the potential for biomass and biogas development is high. Regarding widely available resources, this type of renewable energy has the greatest potential for development, which could reduce the dependence on fossil fuel imports. This energy type is also suitable for development in urban environment regarding energy consumer density and reasonable solutions for energy transfer from cogeneration stations. In recent years another type of renewable energy sources – wave energy – have globally developed. Even though the global energy potential of wave energy is high, the technology is lagging behind to the technology of other types of energy resources. In addition, there is lack of local scale research studies

regarding wave energy potential in the Baltic Sea region, which is also an obstacle to successfully wave energy development in Latvia.

Table 1

Summary of the advantages, disadvantages and development perspectives regarding renewable energy in Latvia

Energy type	Advantages	Disadvantages	Perspectives in Latvia
Wind energy	• No raw materials are needed • Inexhaustible energy resource	• Disturbed bird migration paths • Low speed of the wind flow • Energy storage challenges • Unpredictability	• A small potential for the development of wind power. Feasible zones for development is the Baltic sea Kurzeme coastal region, both land and sea. • Measurements of the wind flow are required
Solar energy	• No raw materials are needed • Inexhaustible energy resource	• Energy storage challenges • Low amount of sunny hours per year • High-cost technologies • Low efficiency	• Limited solar energy development potential • Possible deployment on the roofs of the buildings
Geothermal energy	• No raw materials are needed • Inexhaustible energy resource	• Low power – suitable for households • Insufficient groundwater temperature in Latvia	• Minimal development opportunities in the southwest and central regions of Latvia
Water energy	• Significant installed power • Possibility to produce electricity, when demanded • Possibility to accumulate electricity	• Negative environmental impact	• Hydropower already provides a significant part of the electricity demanded. Further development is possible through small hydroelectric power plants.
Biomass/biogas	• Widely available sources • Reduces the dependence of fossil fuel imports • Various technologies	• Primary processing of raw materials is required	• Good potential for future development throughout the territory of Latvia
Wave energy	• High global energy potential (especially on the shores of the oceans)	• Technology is lagging behind other types of energy resources • No local scale research studies	• Minimal development perspectives

Source: author`s construction based on Central Statistical Bureau of Latvia, 2016, Eurostat, 2017, Latvian Environment, Geology and Meteorology Centre, 2018, Ministry of Agriculture of Latvia, 2018, Solargis, 2016.

The potential of renewable energy source potential in urban environment therefore was being taken into account regarding the situation in the territory of Latvia.

To sum up, hydropower already has a significant impact on providing demanded energy in Latvia. Further development regarding renewable energy source development relies on biomass and biogas, but overall potential of renewable energy sources in Latvia is insufficient to cover the rising demand of energy, what leads to seeking for other types of energy.

2. Nuclear energy and nuclear safety

The urban environment is often marked as an industrial zone. Producing companies demand low-cost energy in order to be competitive towards other companies. Demanded stable low cost energy can be produced by nuclear power plants.

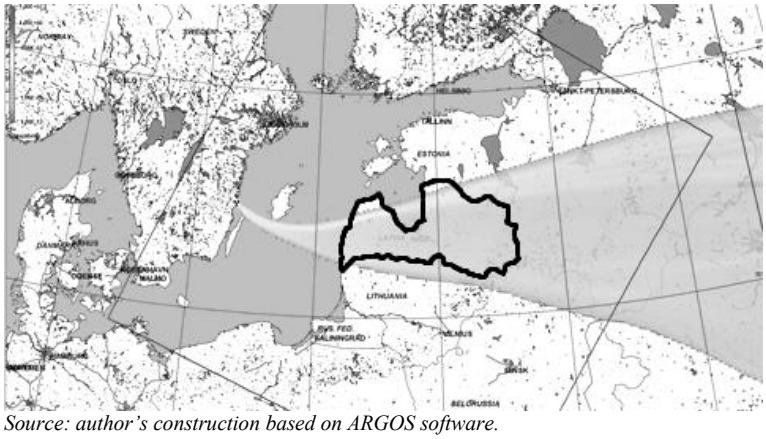
Levelised cost of energy studies show that nuclear energy produced by nuclear power is more beneficial than small hydroelectric power plants, wind turbines, natural gas stations and sun collectors, and the costs are approximately equivalent to 0,08 USD/kWh (Open Energy Information, 2015). However, these costs include all the costs, which are required in order to execute decommissioning and dismantling of the nuclear power plant after its service life, which means, that the energy-producing costs during the service life of nuclear power plant are even lower, which makes nuclear power even more economically attractive.

Main advantages of nuclear power are permanently available high capacity, stable electricity price and the fact, that no emissions of greenhouse gases are being generated, which is in accordance with preventive measures regarding global warming. Nuclear power provides opportunities for the society. Nuclear power plants are built for humanitarian purposes - to provide people with electricity, heat energy, drinking water, without producing greenhouse gas emissions. In addition, the Uranium-238, which is used as raw material in order to produce nuclear energy is not used for any other purposes. On the other hand, high construction cost of the original nuclear power plant might not be profitable in national scale regarding small-economic countries like Latvia, which might lead to collaboration between countries, which might delay the development, planning and execution of the construction of the nuclear power plant. Another disadvantage, which might be the main obstacle of successful nuclear energy development is the fact, that environmentally hazardous radioactive waste and spent fuel are generated during the service life of nuclear power plants. The management and monitoring of spent fuel and radioactive waste will also be a burden for future generations, because the danger can remain up to 4.47 billion years regarding the half-life period of Uranium-238. Additionally, there is lack of methods and technologies in order to manage all kinds of radioactive waste. The increasing number of nuclear power plants will require additional radioactive waste storages to be developed and maintained in the long run, which will result in decreasing the areas of economical land, if waste-free nuclear power plants are not being discovered or another solution for solving this problem is not being introduced. Vulnerability against terrorist attacks also should be considered as the nuclear power development interfering factor. From the society`s point of view, the greatest disadvantage and threat is the potential threat to the environment and health in case of a nuclear accident. Even nowadays humanity senses the consequences of 'Chernobyl' (1986) and 'Fukushima' (2011) disasters, and these events have granted attention and focus on the importance of radiation and nuclear safety. Incidents also form the need for analysis of the consequences of nuclear accidents and disasters.

The authors of the article made predictions about the consequences of a nuclear accident, assuming that there is a leak of radioactive substances from one of the nuclear power plants close to Latvia. Specialized program 'ARGOS' (Accident Reporting Guidance and Operational Support) was used to carry out these predictions. ARGOS is a software system for helping organizations that manage emergencies to make the best possible decisions in situations involving the release of hazardous chemical, biological, radiological, nuclear (CBRN) materials into the atmosphere. ARGOS software is owned by PDC-ARGOS and the Technical University of Denmark, which owns all rights to the RIMPUFF software, as well as the reactor database and card data is the property of Danish Emergency Management Agency. The agreements about the use of software and data are signed between these organizations and the Radiation Safety Centre of State Environmental Service of the Republic of Latvia, which cooperated with the authors of the scientific article regarding of carrying out predictions of consequences of nuclear accidents (PDC-ARGOS, 2014).

In order to assess the preparedness of nuclear accidents across different regions of Latvia, the authors made possible predictions of the consequences of nuclear accidents by looking at 3 of 4 nuclear power plants located less than 300 kilometers from the Latvian border – Oskarshamn, Loviisa and Leningrad nuclear power plants.

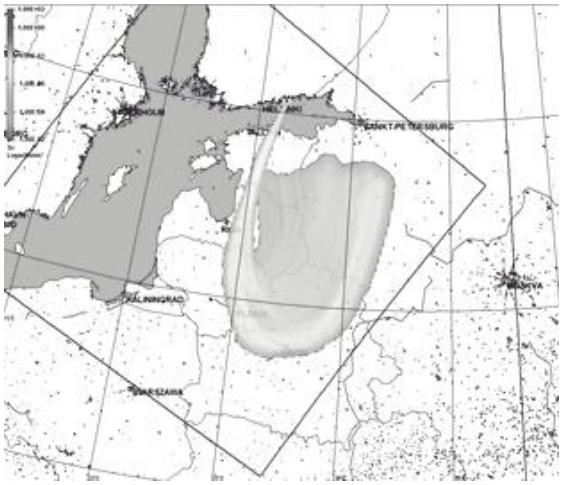
Figure 1 shows the predicted spread of atmospheric radioactive contamination, if the leak from the Oskarshamn nuclear power plant would have started January 5, 2018, at 18:57 and continued until January 7, 2018, at 18:03. Theoretically, it is a 48-hour forecast over the relevant period based on baseline data and weather conditions, especially the direction of wind and speed, which mainly affects the direction of the radioactive cloud. According to the forecast, it can be concluded, that a remarkable western wind would transmit the radioactive cloud across the Baltic Sea. The cloud would hit almost entire territory of Latvia. Taking Iodine pills and staying indoors would be appropriate preventive measures regarding this scenario.



Source: author's construction based on ARGOS software.

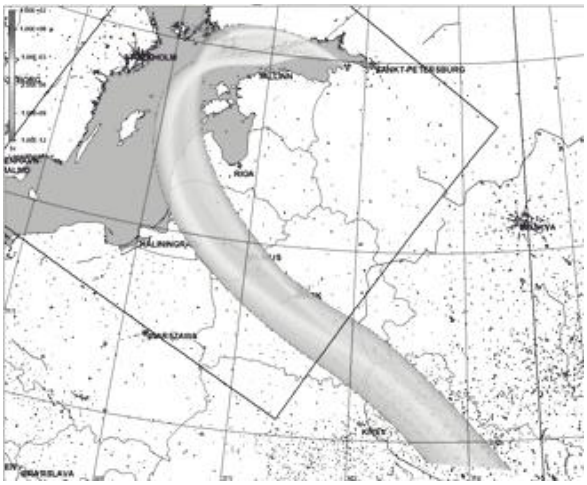
Fig. 1. **Emergency forecast of Oskarshamn nuclear power plant**

Figure 2 shows the predicted atmospheric radioactive contamination, if the leak from the Loviisa nuclear power plant would have started February 5, 2018, at 18:57 and continued until February 7, 2018, at 00:01. Figure 3 shows the predicted atmospheric radioactive contamination, if the leak from the Leningrad nuclear power plant would have started January 29, 2018, at 07:31 and continued until January 31, 2018, at 02:09. It can be seen, that part of the territory of Latvia would have been affected by the radioactive cloud in both figures. Regarding these forecasts, the unpredictability of wind and weather conditions is visible. Even though only a part of the territory of Latvia would be affected by radioactive cloud, all the inhabitants should pay attention to the mass media and orders from the government. Appropriate preventive measures regarding these scenarios would be taking Iodine pills, staying indoors and following the information, using radio and television sets.



Source: author's construction based on ARGOS software.

Fig. 2. **Emergency forecast of Loviisa nuclear power**



Source: author's construction based on ARGOS software.

Fig. 3. **Emergency forecast of Leningrad nuclear power plant**

The authors of the article selected previously described accident scenario forecasts of the nuclear power plants in order to show that the territory of Latvia or part of it is exposed to a radiation dose, which exceeds the radiation natural ambient background level. It should be understood, that in with other condition and the potential incident in different time, the territory of Latvia would not be affected by radioactive cloud regarding these incidents. These forecasts are based on models analyzed and are limited in scope and for particular time, and to assure necessary preparations, when conditions are different. The minimal preventive measures would be necessary to be implemented, to be ready for an accident what emits radioactive pollution into the atmosphere in any nuclear power plant, which is closer than 300 kilometers to the border of Latvia.

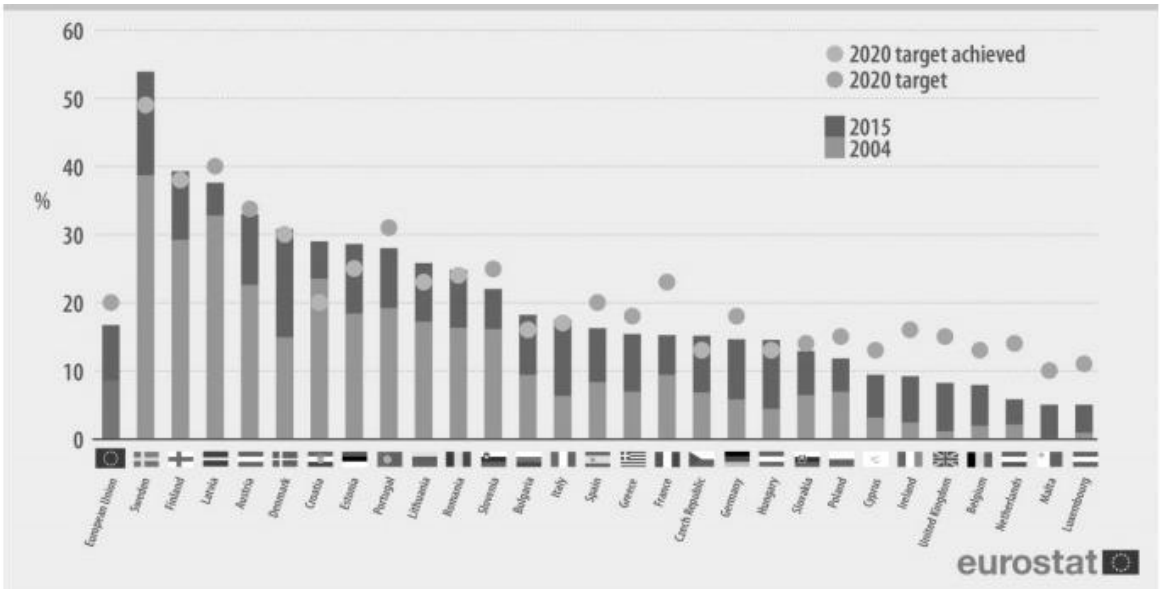
Other preventive measures like food and drinking water control, restrictions on the use of radioactively contaminated food and drinking water, protection of livestock from radioactive contamination, radioactive deactivation of contaminated areas and control of the exposure affected population should be considered regarding nuclear accidents.

The main nuclear and radiation emergency managing organizations are State Fire and Rescue Service of Latvia, State Emergency Medical Service of Latvia, Radiation Safety Centre of State Environmental Service, State Ltd 'Latvian Environment, Geology and Meteorology Centre'. Provision of resources regarding nuclear accident management for organizations is essential to provide successful nuclear and radiation emergency management. Based on the analysis carried out by the authors of the article, there is lack of equipment, vehicles, human resources and financing in order manage national scale emergencies like nuclear accidents.

Authors created research to assess opinions of the citizens of Latvia regarding nuclear power and radiation safety. The research survey questionnaire was created 'Nuclear energy and radiation safety in Latvia' (survey title in Latvian- "Kodolenerģija un radiācijas drošība Latvijā"). Total respondents were 360 who provided anonymous responses to 15 questions in the time period from 27 October 2017 to 11 November 2017. The results of the survey indicate poor awareness of the required actions of the population in case of a radiation or nuclear emergency, it also indicated a negative attitude towards the construction of new nuclear power plant in the territory of Latvia and support for the further development of renewable energy sources. Society often relates the aspects of nuclear energy to Fukushima and Chernobyl disasters, and that interferes to develop reasoned discussion on the real impact of nuclear energy on the country's economy, jobs, enterprise competitiveness and other benefits that provide a better standard of living.

3. Energy storage systems

Regarding Europe 2020 strategy each country of the European Union (EU) has its own goal regarding the share of renewable energy sources in final energy consumption (see figure 4). Latvia has to achieve 40% mark in order to promote the common goal of the EU (Eurostat, 2017).

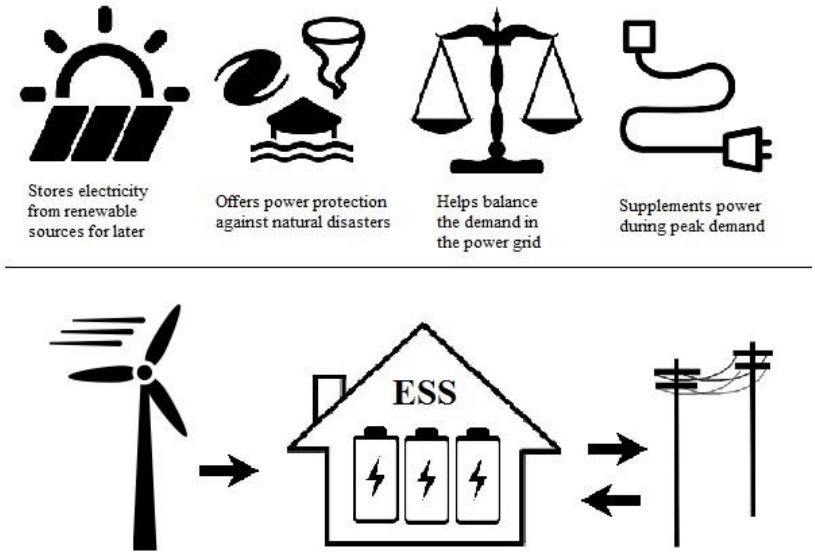


Source: Eurostat, 2017.

Fig. 4. **Share of energy from renewable sources in the EU Member States (in % of gross final energy consumption)**

Further energy strategies will require only the growth of renewable source capacity. However, the potential of renewable source deployment is limited and it has certain issues, one of the main issues is efficient energy storage. These issues in the future could be solved by creating energy storage systems (ESS).

Energy storage systems are the candidate solution to integrate the high amount of electric power generated by volatile renewable energy sources into the electric grid. Different kinds of stationary batteries (lithium-ion, sodium-sulfur and vanadium redox-flow) are considered as energy storage technologies, which differ both in their investment costs and their technical properties, such as round-trip efficiency. However, even though the investment costs of some ESS technologies have decreased over the last few years, only few business models seem to be attractive for investors (Lombardi, P. & Schwabe, F., 2017). Figure 5 shows the operating principle and benefits of energy storage system. The main principle of ESS - it stores the energy received from the renewable sources and whenever it is necessary, supplies it to the grid.



Source: author's construction based on Fortum, 2015.

Fig. 5. **Residential energy storage systems**

An essential aspect of further renewable energy policy strategy would be renewable source integration into urban environment, which could be solved by energy storage systems. In order to support the choice of the best locations of storage units, the studies have been carried out. The methodology, which includes electricity demand, electricity prices and renewable electricity production, is used to optimize the placement of electric energy storage units. Expected attitudes of the main stakeholders towards distributed electric energy storage system implementation, possible regulatory framework options to define the distributed energy storage system business model should be considered (Gonçalves, J., Martins, A., & Neves, L., 2016).

Energy storage challenges regarding wind and solar energy solved by energy storage systems is a huge accomplishment towards providing sustainable green energy integration in cities and rural areas.

Conclusions, proposals, recommendations

The authors of the article have made following conclusions:

1. Renewable energy source development in Latvia relies on biomass and biogas due to the widely available resources.
2. Overall renewable energy source potential in Latvia is limited to cover the growing demand for electricity.
3. In order to become an energy independent country, it is necessary to evaluate the integration of new types of energy sources, for example, nuclear energy, which would affect the aspects of radiation safety and nuclear safety in Latvia.
4. The current provisioning of resources for managing the consequences of a radiological or nuclear emergency is insufficient, so in the current situation the preparation procedures and protocols to request assistance from other countries and international organizations should be considered as most viable short-term plan.
5. The awareness level of the survey respondents regarding radiation safety and nuclear safety issues is low and inadequate.
6. The attitude of survey respondents towards the construction of a potential nuclear power plant in Latvia is negative.
7. The survey indicates preference of respondents to further development of renewable energy sources in Latvia.
8. Iodine-containing substances and staying indoors are primary preventive measures to avoid exposure, as for model analysis in ARGOS situation evolvement is forecasts for most probable accident types in the nuclear power plants near Latvia.
9. Including development of the renewable sources in an urban environment is an essential factor to help achieve the goals of Europe 2020 strategy and Paris Agreement regarding the climate change combating.
10. Energy storage systems are the candidate solution for integrating renewable energy into urban environment.

Considering the mentioned conclusions following may be recommended:

1. To increase the awareness of society for basic action scenarios regarding radiation and nuclear safety, the Radiation Safety Centre of State Environmental Service of the Republic of Latvia would have to develop and provide educational material for society on radiation and nuclear safety.
2. To plan and execute regular coordination and emergency plan execution training involving all responsible organizations including municipalities;
3. It is recommended for Ministry of Economics of Latvia to prepare informative materials to raise the level of awareness of the society on nuclear energy.

4. Execute local-scale research and development studies regarding energy storage systems in order to seek for solutions in integrating renewable sources into urban environment in Latvia.

Authors recommend to carry out further research. It should include data of national energy mix of Latvia. It would reflect the place of Latvia in the context of European Union. Information of energy exports/imports percentages of European Union countries would indicate countries that should strengthen the relevance of search for renewable energy sources. Further research would be useful and should be continued.

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